

The impact of a nap opportunity during the night shift on the performance and alertness of 12-h shift workers

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SUMMARY The purpose of this workplace evaluation was to assess the effects on performance, alertness and subsequent sleep of strategic napping on 12-h overnight shifts. In a counterbalanced crossover design, 24 male aircraft maintenance engineers working in a forward rotating 12-h shift pattern volunteered to take part in the study for two work weeks. During the experimental week, each subject was given the opportunity to take a 20-min nap at work between 01:00 and 03:00 h on each of their two overnight shifts. On the control week no naps were taken on the night shifts. A computerized neurobehavioural test battery was employed to assess performance and subjective levels of fatigue at the beginning and end of each night shift, and pre- and postnap. Subjects were also asked to rate how near they had come to falling asleep while driving to and from work. The results revealed that taking a single 20-min nap during the first night shift significantly improved speed of response on a vigilance task measured at the end of the shift compared with the control condition. On the second night shift there was no effect of the nap on performance. Taking a short nap during either night shift had no significant effect on subjective ratings of fatigue, the level of sleepiness reported while driving to and from work, or subsequent sleep duration and sleep quality. Overall the results suggest some promise for a short duration nap taken in the workplace to counteract performance deficits associated with the first night shift.

KEYWORDS napping, night shift, fatigue, performance, sleep

INTRODUCTION

Worldwide, there is growing demand for 24-h access to services such as transportation, telecommunications, health care, and entertainment (Costa 1997). In an attempt to address these requirements, prolonged and continuous work schedules are becoming increasingly commonplace in many work settings (Wedderburn 1996). An example of this type of schedule is the compressed work week where shift duration is lengthened resulting in fewer actual work days and more consecutive days off.

However, the nature of such schedules places extra demand on workers for sustained optimal performance. At the same

time, compressed schedules engender sleep loss and circadian disruption, especially when extended night shifts are introduced (Åkerstedt 1991; Rosekind *et al.* 1995). As a result, workers can experience increased sleepiness, decreased performance and attentional deficits that pose potential problems for safe and productive operations (Åkerstedt 1991; Dinges 1995; Duchon and Smith 1993; Krueger 1989; Pilcher and Huffcut 1996; Williamson and Feyer 2000). These factors take on particular importance in industries where public health and safety are a concern such as in transport, emergency health care and in nuclear or chemical power plants (Mitler *et al.* 1988). Relatively minor errors made in these situations can have catastrophic effects. In addition, sleep-deprived night workers driving home in the early hours of the morning are at an increased risk of falling asleep at the wheel (Horne and Reyner 1999; Lyznicki *et al.* 1998; Pack *et al.* 1995).

Given the often critical need for optimal functioning under sustained and prolonged work conditions there is good reason

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for researchers and managers to search for effective strategies that can be used to counteract sleepiness and promote alertness in the operational setting, especially during the night shift. Napping, defined as any sleep period <50% of a person's average nocturnal sleep duration (Dinges *et al.* 1987), is one strategy receiving increased attention as a possibly useful fatigue countermeasure. Short naps (30 min–3 h) taken in the laboratory under simulated conditions of night work have been shown to attenuate the effects of sleepiness and to improve performance relative to no sleep at all (Bonnet 1991; Bonnet *et al.* 1995; Gillberg 1984; Matsumoto and Harada 1994; Rogers *et al.* 1989; Sallinen *et al.* 1998; Scheitzer *et al.* 1992). But to date, there have been few operational evaluations of the benefits for performance and alertness of napping in the workplace context. Two experimental field studies have investigated the effect of naps taken in the cockpit on the performance of aircraft pilots (Rosekind *et al.* 1994; Simons and Valk 1997). In both cases, performance on a vigilance task was improved following a 40-min in-flight nap compared with a no-nap condition. The need still exists however, for field-based studies designed to evaluate the usefulness of naps of taken in other workplace settings.

In line with current work trends in New Zealand and internationally, aircraft maintenance engineers employed by a large international airline in New Zealand work a compressed work week that includes extended day shifts as well as extended night shifts. An earlier study of this group of workers indicated that the introduction of extended shifts resulted in increased levels of reported fatigue, particularly on the night shift (Frazer *et al.* 2000). Rest breaks for these workers, while frequent in number, are often short in duration (i.e. <40 min). Taking a short nap during a scheduled rest break at work may be a useful strategy for helping these workers minimize their level of fatigue and maintain alertness on the night shift. However, there have been no operationally based investigations into the benefits or otherwise of such scheduled short duration naps for performance and alertness. The main purpose of the present study was to identify the benefits (if any) of the opportunity to take a single nap on the night shift in the workplace for subsequent performance and alertness of a group of aircraft maintenance engineers.

For napping to be even considered for use in operational settings, its positive effects need to be balanced against any possible detrimental consequences. One potential negative effect of napping is sleep inertia, or the drowsiness and decreased performance that can accompany awakening from slow wave sleep. This effect can last from a couple of minutes to half an hour and would clearly be a consideration in an operational setting where a quick and accurate response is required after awakening (Åkerstedt *et al.* 1989; Rosekind *et al.* 1995). Long naps may also interfere with the quality and duration of subsequent sleep periods and thereby interfere with recovery between periods of work (Åkerstedt *et al.* 1989). The present study also sought to determine the effect of the nap on subsequent sleep and the extent of persistent sleep inertia following a single 20-min nap.

METHODS

Subjects and shift pattern

Twenty-four male aircraft maintenance engineers aged 21–59 years (mean age 34.75; SD 10.13) were recruited for the study. Each had a minimum of 4 months experience (maximum 18 months) working a forward rotating 12-h shift pattern. The shift pattern consisted of two 12-h day shifts followed by two 12-h night shifts, then four consecutive days off: DDNRRRRR/DDNRRRRR, where D = day 07:00–19:00 h, N = night 19:00–07:00 h, and R = rest day.

Prior to the commencement of the study, each subject was provided with an information sheet outlining the project and given the opportunity to have any questions answered. Participation was voluntary and once a consent form had been signed, a code number was assigned to each subject to protect anonymity. The project was reviewed and approved by the ethics committee of the University of Otago, Dunedin, New Zealand.

Study design

Subjects participated for two work weeks in a counterbalanced crossover design study illustrated in Fig. 1. Under the 20-min nap condition, participants were given the opportunity to take a single 20-min nap at work between 01:00 and 03:00 h on each of the two 12-h night shifts. The timing of the nap was chosen to occur as early as possible within the shift prior to the circadian nadir normally apparent around 04:00–06:00 h. This was designed to minimize any possible combined effect of sleep inertia resulting from the nap with the natural dip in alertness that occurs around the circadian nadir. A temporary napping facility was provided in the aircraft hangar as the company did not allow napping at work under normal circumstances. Under the control condition, the subjects took a break from work (watched television and chatted with others), but did not sleep.

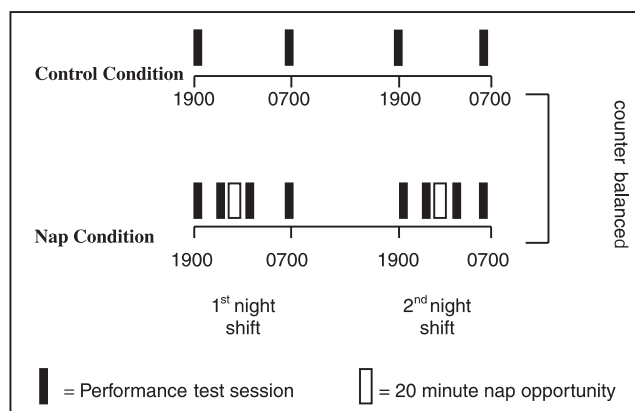


Figure 1. The experimental performance test and napping schedule. Each test session consisted of three subjective fatigue rating scales, a 2 min simple reaction time task and a 10 min vigilance task. For the pre- and postnap test sessions the vigilance task was shortened to 5 min.

The subjects were not permitted by the company to nap at any other time at work unless taking part in the experimental condition of this study. Objective and subjective measures of alertness and performance were obtained at the beginning and end of the night shifts. To test for the existence of long lasting sleep inertia following the nap, objective and subjective measures of alertness and performance were carried out immediately preceding and 30 min following the nap. Subjects carried out their normal work duties within the aircraft hangar when not fulfilling the requirements of the study.

Measures

Questionnaires

A short questionnaire was administered at the start and end of each shift to obtain information from the subjects concerning the sleep obtained during their nap and their level of sleepiness while driving to and from work.

Sleep during the nap. After their scheduled nap, participants were asked to report via a questionnaire at what time they had taken their nap, whether they thought that they had fallen asleep or not during their nap, the duration of their sleep and the approximate sleep latency. Under the control condition, the engineers were asked to report whether they had taken any unscheduled sleep during the night shift. One person reported doing so and his data was not included in the final analysis.

Sleepiness while driving to and from work. Subjects were asked to rate how close they had felt to falling asleep while driving to and from work on a visual analogue scale (VAS) with bi-polar points of 'nowhere near to falling asleep' (score = 0) and 'very near to falling asleep' (score = 100). A mean score (out of 100) was obtained for the start and end of each shift under the control and experimental conditions.

Performance test battery

A battery of performance tests from the Information Processing and Performance Test System (Williamson and Feyer 2000; Williamson *et al.* 2001) was presented via a computer screen to subjects seated in a quiet room in the workplace. The test battery consisted of three subjective fatigue rating scales, a 2-min simple reaction time task and a 10-min vigilance task. Before data collection began, each subject practised the tests to minimize any learning trends or novelty effects. The tests were presented at the beginning and end of each 12-h night shift (19:00 and 07:00 h) during both experimental and control weeks. To examine any possible effects of long lasting sleep inertia, the test battery was also presented to the subjects immediately preceding, and 30 min after the workplace nap on the night shift. In this instance, the vigilance task was shortened to 5 min duration. The subjects received no feedback about their results while the study was being carried out.

Subjective ratings of fatigue. Three VAS were presented to the subjects (scored 0–20) with bi-polar points of: fresh/tired, clear headed/muzzy headed and very alert/very drowsy. Subjects used a computer mouse to position a cursor at some point between the anchor points to reflect their current level of fatigue. Because of the finding that the data from each of the scales was almost identical, a mean score out of 20 was obtained using the three scales to give an overall fatigue rating, 0 = very fresh and 20 = very tired.

Simple reaction time task. This task required subjects to press a button on a computer keypad as quickly as possible when a yellow circle (diameter 3 cm) changed colour to red as it slowly moved around a computer screen. Subjects were instructed to concentrate on both speed and accuracy of response. The task duration was 2 min with 40 circle colour changes. The minimum interstimulus interval was set at 2 s with a maximum response time of 1 s. Mean response latency (MRL) of correct responses (ms) and missed responses (maximum of 40) were collected and stored on computer.

Mackworth clock vigilance task. Subjects were presented with a circle of 25 dots on a computer screen. Each dot flashed in a clockwise sequence. When a dot flash was omitted, subjects were required to press a response button as quickly as possible. Subjects were instructed to concentrate on both speed and accuracy of response. The task was 10 min in duration, flashes lasted 500 ms and 10 flashes (trials) were omitted. The minimum interstimulus interval, which varied randomly, was 45 s and the maximum response time was set at 10 s after which time a missed response was recorded. For the pre- and postnap testing, the vigilance task was shortened to 5 min duration with five flashes omitted, but all other parameters were as outlined above. Response latency in milliseconds (ms) for each correct individual trial and the number of missed responses were collected and stored on computer.

Actigraphy and sleep diaries

Actigraphy was used in conjunction with subjective sleep diaries to obtain data on the subjects' sleep patterns continuously throughout the course of the study. In addition, actigraphy data were used to corroborate the subjective reports on nap sleep length and also to confirm that the subjects did not sleep under the control condition. Actigraphy was not used for analysis of the quality of any sleep periods less than 1 h in duration such as the workplace nap, because current software is only designed to analyse the quality of sleep periods greater than 1 h long.

Each subject wore an AW64 Actiwatch (Minimitter™, Mini Mitter Co. Inc., Bend, OR, USA) on their non-dominant wrist from commencement to completion of participation in the study. The actiwatch consists of a small water resistant box (28 × 25 × 11 mm) containing a battery powered accelerometer. This device monitors the occurrence and degree of motion and stores the information as activity counts per epoch.

An epoch length of 1 min was used and the counts were downloaded via a wireless connection with a PC computer using Actiware-Sleep Version 3.00™ software (Mini Mitter Co. Inc.). An algorithm, set at medium sensitivity, automatically scored each epoch as either 'sleep' or 'awake'. The subjective sleep diaries kept by the engineers throughout the course of the study were used to verify that the sleep periods signalled by the actiwatch were in fact periods of sleep or attempted sleep and were not periods of inactive behaviour such as reading a book. Although discrepancies were rare, sleep periods apparent on the actiwatch data were only counted as sleep and analysed further if the subject reported sleeping or attempting to sleep during that period.

Sleep measures relevant to this study were total sleep duration (h) and a movement and fragmentation index (%). Both of these measures were calculated for the day sleep periods following the control night shifts and the night shifts containing the naps. These were used to examine the impact of the workplace nap on subsequent sleep. Total sleep duration represented the amount of time between sleep start and sleep end that was scored as sleep according to the Actiware-Sleep algorithm and verified as attempted sleep by the subjective sleep diaries. The movement and fragmentation index gives an indication of the level of restlessness and thereby quality that occurs during a particular sleep period. This was calculated by summing the percentage of assumed sleep time spent moving with the percentage of immobile phases that were 1 min in duration for each sleep period.

In addition, the duration of wakefulness (h) prior to the performance and alertness tests being carried out at the end of the night shifts under both conditions was obtained. This was calculated as the mean difference in hours between the time of sleep end from the main sleep period (> 4 h duration) on the day of the anticipated night shift and the time of the test session carried out at the end of that night shift (07:00 h).

Data analyses

Paired *t*-tests were used to test for significant differences in sleep duration, fragmentation of sleep, duration of wakefulness between the control and nap conditions, between pre- and postnap subjective ratings of fatigue and mean number of missed responses. Mixed model analysis was performed on all performance and subjective fatigue data collected at the start and the end of the night shifts using PROC MIXED in SAS (SAS Institute Inc., Cary, NC, USA) with shift (i.e. first night, second night), point of shift (i.e. start/end), and condition (i.e. nap/no nap) as factors, plus their interactions. Subjective fatigue data include subjective ratings of fatigue and ratings of sleepiness while driving to and from work. Mixed models are now recognized as the most appropriate way to conduct repeated measures analysis (Everitt 1998). An extra model was run with the addition of sleep during the nap as a factor. In this model, comparisons between the control week and the nap week for performance and subjective fatigue data were made separately for those who reported sleeping during their nap

and those who reported remaining awake. Post hoc comparisons for the performance, subjective fatigue and sleepiness while driving data following the mixed model analysis were carried out by means of the ls means statement using the Bonferroni adjustment. The ls means statement produces an estimate of the mean difference, and its estimated standard error, between the different combinations of the factors specified. These are used to produce a *t*-value and its associated significance level, both unadjusted and adjusted with a Bonferroni correction. No Bonferroni correction was necessary for the pre- and postnap response latency data as only single comparisons were made. In the figures and tables, the observed values are shown, rather than the estimated mean produced from the mixed model.

RESULTS

Sleep during the nap

The engineers took their naps at the appropriate time on the allocated shifts. The median time when the nap was taken on both the first and second night shifts was 03:00 h coinciding with the main night shift break. Half of the engineers (50%) taking a nap during the first night shift reported that they had not fallen asleep during the nap and 42% reported not having fallen asleep during the nap taken on the second night shift. Mean reported sleep duration for those who did report sleeping during the nap was 19 min (± 11.62 SE) on the first night shift and 21 min (± 14.49 SE) on the second night shift. Mean reported sleep latency was 9.92 min (± 4.73 SE) and 13 min (± 8.56 SE) for the first night and second night shift nap, respectively.

Performance on the vigilance task

Table 1 displays the MRL data and the mixed model analysis results for the vigilance task under the no-nap condition and the 20-min night shift nap condition. The unadjusted and adjusted *P*-values (using Bonferroni correction) are shown.

Between the nap and control conditions

At the start of the first night shift (prior to the napping intervention), there were no significant differences in MRL between the nap and control conditions. However at the end of the first night shift following a 20-min nap, MRL was significantly shorter than that measured at the end of the first night shift when no nap had been taken (Table 1). When sleep during the nap was included as a factor in the model, the MRL of those subjects who reported falling asleep during their nap was significantly shorter at the end of the first night shift following the nap compared with the same time point during the control condition $p(t_{1399} > -3.41) = 0.0056$. In contrast, there was no significant difference in MRL on the vigilance task at the end of the first night shift between the control and nap conditions for those who reported remaining awake during their first night shift nap. No significant differences in MRL were found between

Table 1 Mixed model analysis results with post hoc comparisons for response latencies (10 trials), subjective fatigue ratings, and sleepiness while driving ratings measured at the beginning and end of the 12-h night shifts with (nap condition) and without (control condition) a 20-min nap taken on each night shift. Both the unadjusted and adjusted *P*-values are presented

| | <i>Control condition</i> | | <i>Nap condition</i> | | <i>t</i> | <i>df</i> | <i>Unadjusted P</i> | <i>Adjusted P*</i> |
|--|--------------------------|-----------|----------------------|-----------|----------|-----------|---------------------|--------------------|
| | <i>Mean</i> | <i>SE</i> | <i>Mean</i> | <i>SE</i> | | | | |
| Mackworth clock vigilance task | | | | | | | | |
| Response latency (ms) | | | | | | | | |
| Start first night | 791 | 22.2 | 772 | 19.5 | −1.51 | 3030 | 0.13 | 1.00 |
| End first night | 928.1 | 66.8 | 815.7 | 27.7 | −4.15 | 3030 | <0.0001 | 0.004 |
| Start second night | 792.6 | 17 | 786.2 | 19.1 | −0.56 | 3030 | 0.576 | 1.00 |
| End second night | 832.8 | 22 | 821.2 | 47.8 | −2.08 | 3030 | 0.037 | 1.00 |
| Subjective fatigue ratings | | | | | | | | |
| Mean score/20 (higher = worse) | | | | | | | | |
| Start first night | 6.21 | 0.88 | 5.81 | 0.69 | −0.31 | 138 | 0.76 | 1.00 |
| End first night | 10.57 | 0.8 | 11.21 | 0.69 | 0.69 | 138 | 0.492 | 1.00 |
| Start second night | 7.12 | 0.96 | 6.4 | 0.88 | −0.65 | 138 | 0.518 | 1.00 |
| End second night | 9.1 | 0.9 | 9.4 | 0.44 | 0.32 | 138 | 0.747 | 1.00 |
| Subjective ratings of sleepiness while driving | | | | | | | | |
| Mean score/40 (higher = worse) | | | | | | | | |
| Start first night | 12.7 | 3.76 | 9.18 | 2.02 | −0.41 | 122 | 0.683 | 1.00 |
| End first night | 48.2 | 6.46 | 37.59 | 5.75 | −1.99 | 122 | 0.049 | 1.00 |
| Start second night | 19.1 | 4.27 | 14 | 2.24 | −1.08 | 122 | 0.284 | 1.00 |
| End second night | 41.44 | 7.3 | 38.88 | 9.07 | −1.32 | 122 | 0.188 | 1.00 |

*Post hoc comparisons following mixed model analysis were carried out using Bonferroni adjustment.

conditions, either at the start or at the end of the second night shift (see Table 1). There was no difference in MRL between the control and nap week for those who reported sleeping during their second night shift nap and those who reported not sleeping. The mean number of missed responses measured on the vigilance task did not significantly differ between conditions on either night shift or between those who reported sleeping during the nap and those who reported not sleeping.

Between the start and end of the night shifts

Mixed model analysis across the night shifts under the control condition showed that the MRL measured at the end of the first night shift was significantly slower than that measured at the start of the same shift ($P(t_{3030} > 4.940) = 0.0001$ (adjusted using Bonferroni correction)). The MRL measured at the end of the second night shift did not significantly differ from the start of the same shift under the no nap condition. Under the nap condition, the mean response latencies measured at the start and end of either night shift were not significantly different.

Performance on the simple reaction time task

There were no significant differences in MRL or mean number of missed responses either between conditions or between the start and end of the night shifts.

Subjective ratings of fatigue

Table 1 shows the mean subjective fatigue ratings given by subjects at the start and end of each shift under both

experimental conditions with mixed model analysis and posthoc comparison results.

Between the nap and control conditions

Self-reported fatigue levels did not significantly differ between the control and nap conditions at either the start or the end of the night shifts. There was no significant difference in subjective fatigue ratings between conditions for those who reported sleeping and those who reported remaining awake during their nap.

Between the start and end of the night shifts

Under the nap condition, reported levels of fatigue were significantly higher at the end of the first night shift compared with the start of the same shift ($P(t_{138} > -5.19) = 0.000$ (adjusted using Bonferroni correction)). Under the control condition, reported levels of fatigue were also significantly higher at the end of the first night shift compared with the start of the first night shift ($P(t_{138} > -4.16) = 0.002$ (adjusted using Bonferroni correction)). Reported levels of fatigue did not significantly differ between the start and end of the second night shift under either condition.

Sleepiness while driving to and from work

Table 1 displays the mean ratings for how near the subjects felt to falling asleep while driving to and from their 12-h night shifts with mixed model analysis and posthoc comparison results.

Between the nap and control conditions

The mean subjective rating of sleepiness while driving to or from work did not significantly differ between the nap and control condition on either night shift. There was also no significant difference in mean subjective ratings of sleepiness while driving between conditions for those who reported sleeping and those who reported remaining awake during their nap.

Between the start and end of the night shifts

The subjects reported feeling significantly nearer to falling asleep while driving home at the end of the first night shift under both conditions compared with how they felt when driving to each of the night shifts [control condition $P(t_{122} > -6.72) = 0.0000$; nap condition $P(t_{122} > -5.34) = 0.0000$]. While driving home from the second night shift under the control condition, the engineers reported feeling significantly nearer to falling asleep compared with how they felt driving to the second night shift $P(t_{122} > -4.40) = 0.0006$. There was no significant difference in the mean rating for how close the subjects felt to falling asleep while driving to or from the second night shift that had contained a workplace nap.

Sleep inertia

Mixed model analysis revealed that the mean postnap rating of subjective fatigue on the first night shift was significantly higher than the mean prenap rating of subjective fatigue (Table 2). On the second night shift, the mean prenap rating of subjective fatigue and the mean postnap rating did not significantly differ.

The MRL on the vigilance task on the first night shift was significantly longer at the postnap measurement occasion compared with the prenap occasion (Table 2). On the second

Table 2 Subjective fatigue ratings and response latencies (five trials) on the vigilance task measured immediately preceding and 30 min following a 20-min nap taken on each 12-h night shift

| | <i>Prenap</i> | | <i>Postnap</i> | | <i>t</i> | <i>df</i> | <i>P</i> |
|--------------------------------|---------------|-----------|----------------|-----------|----------|-----------|----------|
| | <i>Mean</i> | <i>SE</i> | <i>Mean</i> | <i>SE</i> | | | |
| Subjective fatigue ratings | | | | | | | |
| Mean score/20 (higher = worse) | | | | | | | |
| First nightshift | 8.87 | 0.69 | 10.12 | 0.53 | 2.44 | 19 | 0.025* |
| Second nightshift | 8.82 | 0.69 | 9.94 | 0.75 | 1.94 | 17 | 0.07* |
| Mackworth clock vigilance task | | | | | | | |
| Response latency (ms) | | | | | | | |
| First nightshift | 755.5 | 18.4 | 827.3 | 35.7 | 2.47 | 139 | 0.015† |
| Second nightshift | 774 | 21.14 | 793.8 | 24.2 | -0.21 | 126 | 0.832† |

*Paired *t*-test.

†Mixed model analysis – single comparisons.

night shift, the MRL on the vigilance task did not significantly differ pre- and postnap. The MRL on the simple reaction time task did not significantly differ between the pre- and postnap time-points on either night shift. The mean number of missed responses on both the vigilance task and the simple reaction time task did not significantly differ between the pre- and postnap time-points on either night shift.

Sleep duration and quality

The mean sleep duration of the main day sleep period following the first night shift with a nap [05.47 h (\pm SE 0.41)] and without a nap [05.51 h (\pm SE 0.31)] did not significantly differ. The mean sleep duration of the main day sleep period following the second night shift with a nap [04.39 h (\pm SE 0.37)] and without a nap [04.41 h (\pm SE 0.45)] did not significantly differ. The mean fragmentation index (restlessness) of the main sleep period following the first night shift with a nap [27.17% (\pm SE 2.82)] and without a nap [37.5% (\pm SE 9.29)] did not significantly differ. The mean fragmentation index of the main sleep period following the second night shift with a nap [27.04% (\pm SE 3.35)] and without a nap [22.24% (\pm SE 2.42)] did not significantly differ.

Table 3 shows the duration of wakefulness measured via actigraphy (time elapsed since last main sleep period) for engineers prior to the testing sessions carried out at the end of the night shifts. Under both the control and nap conditions, the engineers' total duration of wakefulness measured at the end of the first night shift was significantly longer than that measured at the end of the second night shift.

DISCUSSION

Consistent with previous research on night shift performance (see review by Åkerstedt 1991), the present study showed a significant decline in speed of performance on a vigilance task by aircraft maintenance engineers on the first night shift. However, a single 20-min nap taken at 03:00 h in the workplace during the first night shift significantly improved performance and restored it back to baseline levels measured

Table 3 Duration of wakefulness prior to the end of each night shift with (nap condition) and without (control condition) a 20-min nap taken on each 12-h night shift

| | <i>At end of first night shift</i> | | <i>At end of second night shift</i> | | | | |
|-----------------------------|--|-----------|---|-----------|----------|-----------|------------|
| | <i>Mean</i> | <i>SE</i> | <i>Mean</i> | <i>SE</i> | <i>t</i> | <i>df</i> | <i>P</i> * |
| Duration of wakefulness (h) | | | | | | | |
| Control condition | 23.02 | 0.37 | 16.32 | 0.37 | 16.04 | 16 | <0.001 |
| Nap condition | 23.02 | 0.4 | 16.46 | 0.34 | 13.84 | 18 | <0.001 |

*Paired *t*-tests.

at the beginning of the shift. Moreover, the nap had no effect on the main sleep period taken after the shift.

Performance on the vigilance task

Our finding of the positive effect of a nap on performance during the first night shift confirms and extends the results of previous laboratory-based napping studies where naps of longer duration were used (¹⁴Dinges *et al.* 1987, 1988; Gillberg 1984; Rogers *et al.* 1989; Sallinen *et al.* 1998). For example, Gillberg (1984) found that a 1-h nap taken at either 21:00 or 04:30 h resulted in significantly faster response times on a 10-min reaction time test taken at 07:00. Sallinen *et al.* (1998) investigated the effect of a short nap (30 or 50 min) taken at 01:00 or 04:00 h on performance. They found that either nap significantly decreased the percentage of lapses measured on a two-choice reaction time task during the second half of the night shift. In two aviation-based napping studies, the performance of a group of pilots on a vigilance task was significantly improved following a 40-min nap taken in the cockpit during a long haul flight compared with no nap (Rosekind *et al.* 1994; Simons and Valk 1997). Taken together, these results show that short periods of sleep obtained during the night shift can result in positive benefits to performance not only in a laboratory setting under controlled conditions, or restricted work environments like an aircraft cockpit, but also in a workplace setting such as an aircraft maintenance hangar. Further research is needed to establish how soon after a nap, under operational conditions, the improvements in performance become apparent, as well as the extent to which they persist over time.

Accuracy of performance was well maintained by the engineers on the vigilance task even when speed of performance had significantly deteriorated at the end of the first night shift under the control condition. This result suggests that the engineers traded off speed of response to maximize and maintain accuracy in the face of increasing sleep loss. Undeniably, the maintenance of accurate performance is of critical importance in aircraft maintenance given the implications for public safety. However, aircraft engineers commonly experience pressure situations that require both accurate and timely response in order to get a specific job carried out in a specified time. Under these operational circumstances, the same trade-off of speed for accuracy cannot be made. The computerized tests used in the present study are not a measure of overall operational performance. On the other hand, attention and rapid response are critical features of many tasks carried out by aircraft maintenance engineers. Therefore, these data provide information about operational readiness and signal changes in performance capacity for the engineers.

Subjective fatigue

At the end of the first night shift under the control condition when performance by the engineers was poorest, subjective ratings of fatigue were highest. This finding is in agreement

with two previous studies employing the same tests where significant decrements in performance on the Mackworth Clock vigilance task were found at times when self-rated alertness was lowest (Williamson and Feyer 2000; Williamson *et al.* 2001). Interestingly however, taking a nap during the first night shift did not alleviate the significantly increased subjective fatigue levels reported at the end of the first night shift even though performance was significantly improved. This finding is most probably not because of the effects of sleep inertia, as any such effects should have dissipated in the 4 h following the nap before the sleepiness rating scales were administered. Similar results have been reported previously where subjective alertness or mood were not improved following a nap when clear positive effects on performance had been measured (Dinges *et al.* 1987, 1988; Gillberg 1984; Rosekind *et al.* 1994). In some cases, however, improvements in both objective and subjective measures of alertness following naps have been reported (Caldwell and Caldwell 1998; Della Rocco *et al.* 2000; Matsumoto and Harada 1994; Simons and Valk 1997). Therefore under both operational and laboratory settings subjective sleepiness appears to, at times, respond in a different fashion to the effects of napping compared with other more objective measures of sleepiness such as performance on a vigilance task. Subjective sleepiness may be more influenced by contextual variables (Dinges *et al.* 1987). Or it may be that a nap of longer duration or better quality would have been required to restore subjective alertness at the end of the shift.

Performance on the simple reaction time task

Changes in performance were apparent on the vigilance task during the first night shift, however, the engineers exhibited no performance decrements on the simple reaction time task at any point of their shift pattern including the pre- and postnap time-points. Earlier investigations have pointed to task duration as being a powerful determinant of decreased performance in a sleep-deprived person (see review by Dinges and Kribbs 1991). Generally, the longer the duration of a task the greater the likelihood that impairment in performance will become evident early on during sleep deprivation. Therefore in this operational setting, it was anticipated that the longer vigilance task might be more sensitive than the shorter duration simple reaction time task in detecting performance decrements associated with sleep loss.

Sleepiness while driving to and from work

Night-shift workers are at an increased risk of having a sleep related motor vehicle crash compared with day-time workers because of the combined effects of driving while sleepy, driving at vulnerable times of the circadian cycle, and following an extended period of wakefulness (Horne and Reyner 1999; Lyznicki *et al.* 1998; Philip and Mitler 2000). Horne and Reyner (1996) showed that a 15-min nap taken by a sleepy driver between two 1-h monotonous early afternoon drives significantly reduced driving impairments and subjective

sleepiness in a car simulator. In the present study, a single nap of 20 min taken on the night shift had no impact on the level of sleepiness felt while driving home from the night shift some 4 h later although vigilance performance, a key component of safe driving, was improved following the nap. Once more, it may be that the subjective ratings of sleepiness at the wheel lagged behind performance improvement or that perhaps a longer nap would have been required to improve subjective levels of sleepiness while driving.

Sleep during the nap

The chief limitation of this study was that an objective measure of sleep obtained during the nap, using a method such as polysomnography, was not possible in this operational setting. Accurate information was obtained from actigraphy data concerning the duration and timing of the naps, but not sleep quality. According to self-reports, however, only around half of the subjects reported falling asleep during each of their naps. Post hoc analysis revealed that speed of performance on the vigilance task was significantly improved in those subjects who reported sleeping during the nap compared with the control week but not for those subjects who remained awake. In contrast, subjective measures of sleepiness did not differ between those who reported sleeping and those who reported remaining awake. 'Too much noise' was given as the most common reason for lack of sleep during the nap and this finding highlights the challenge of integrating strategies such as napping into the workplace environment. Overall, these results reinforce the fact that the effectiveness of a nap will depend on the interaction of several variables. These include not only the temporal placement of the nap and the duration of prior wakefulness, but also the type of napping environment and the quality and duration of sleep that is obtained.

Shift differences

The significant deterioration in alertness and performance evident on the first night shift under the control condition was not apparent on the second night shift. This 'first night shift phenomenon' where shiftworkers experience increased sleepiness during the first night shift is commonly reported. It reflects the fact that there is generally an extended time of prior wakefulness before the start of the first night shift because of most sleep being taken during the previous night (Åkerstedt 1995; Knauth *et al.* 1980). Duration of prior wakefulness is one important predictor of performance and alertness, and increasing decrements in performance on vigilance tasks as periods of sleep loss increase have been reported previously (Dinges *et al.* 1988; Pilcher and Huffcutt 1996; Williamson and Feyer 2000). This was indeed the case in the present study where the subjects were awake for a significantly longer period of time prior to the end of the first night shift compared with the second night shift. The implications for this group of aircraft engineers are that fatigue management strategies should, in the first instance, be focused around the first night

shift where the most benefits to performance and alertness are likely to be obtained.

Sleep inertia and subsequent sleep

An important finding in this context was that subsequent daytime sleep was not negatively affected by the naps taken on the night shifts. As nightshift workers commonly experience daytime sleep of shorter duration and poorer quality compared with night-time sleep (Åkerstedt 1991), it is preferable that any fatigue management strategy should not be introduced at the expense of efficient recovery sleep. Moreover, for safety reasons, the existence of increased drowsiness or sleep inertia that can sometimes accompany waking from a nap must be considered when implementing such a strategy into an operational setting. In the present study engineers rated their level of fatigue as significantly worse and performed significantly slower on the vigilance task 30 min after their first night shift nap compared with immediately preceding their nap, indicating possible long lasting sleep inertia. By contrast, subjective fatigue and performance was no different pre- and postnap on the second night shift. A variety of factors will contribute to the degree of sleep inertia that follows a nap such as nap length, nap timing, the length of prior wakefulness and depth of sleep during the nap (Naitoh and Angus 1989). In this study, the difference between some of the pre- and postnap measures on each night shift may once again reflect the significantly longer period of prior wakefulness endured by the engineers when working the first night shift in the pattern and the resulting increased need for sleep. It is noteworthy that the level of reported fatigue following the nap on the first night shift was no worse than that at the end of the first night shift under the no-nap condition. The apparent effects of persistent sleep inertia following the first night shift nap would seem to be outweighed by the significant benefits to performance at the end of the shift.

CONCLUSION

Overall, the results demonstrate that the deterioration of performance associated with the first night shift can be counteracted by a 20-min nap taken in the workplace during the night shift. However, further detailed napping studies are necessary to ascertain the optimal duration and quality of sleep required in the operational setting that will result in improvements to subjective levels of fatigue on the night shift.

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